UNITED STATES PATENT APPLICATION FOR:

TUNED POTENTIAL PEDESTAL FOR MASK ETCH PROCESSING APPARATUS

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ATTORNEY DOCKET NUMBER: AMAT/8403/MASK/MASK-ETCH/ARNOLD S

CERTIFICATION OF MAILING UNDER 37 C.F.R. 1.10

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TUNED POTENTIAL PEDESTAL FOR MASK ETCH PROCESSING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to previously filed provisional patent application serial number 60/531,062, filed December 19, 2003, entitled "Tuned Potential Pedestal for Mask Etch Processing Apparatus." The provisional application is incorporated herein by referenced in its entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention generally relates to the fabrication of integrated circuits. More specifically, the invention relates to an apparatus for manufacturing a photomask, or "reticle," useful in manufacturing semiconductors.

Description of the Related Art

[0003] Integrated circuits (IC) are manufactured by forming discrete semiconductor devices on a surface of a semiconductor substrate. An example of such a substrate is a silicon (Si) or silicon dioxide (SiO_2) wafer. To interconnect the devices on the substrate, a multi-level network of interconnect structures is formed. Material is deposited on the substrate in layers and selectively removed in a series of controlled steps.

[0004] Increasing circuit densities have placed additional demands on processes used to fabricate semiconductor devices. For example, as circuit densities increase, the widths of vias, contacts and other features, as well as the dielectric materials between them, decrease to sub-micron dimensions. However, the thickness of the dielectric layers remains substantially constant, with the result that the aspect ratios for the features, *i.e.*, their height divided by width, increases. Reliable formation of high aspect ratio features is important to the success of sub-micron technology and to the continued effort to increase circuit density and the quality of individual substrates and die.

[0005] Reliable formation of high aspect ratio features with desired critical dimensions requires precise patterning and subsequent etching of the substrate. A technique commonly used to form precise patterns on substrates is photolithography. The technique generally involves the direction of light energy through a lens, or "reticle" and onto the substrate. In conventional photolithographic processes, a photoresist material is first applied on a substrate layer to be etched. In the context of optical resists, the resist material is sensitive to light energy, such as ultraviolet or laser sources. The resist material defines a polymer that is tuned to respond to the specific wavelength of light used, and to different exposing sources.

[0006] After the resist is deposited onto the substrate, the light source is actuated to emit ultraviolet (UV) light or low X-ray light, for example, directed at the resist-covered substrate. The selected light source chemically alters the composition of the photoresist material. However, the photoresist layer is only selectively exposed. In this respect, a photomask, or "reticle," is positioned between the light source and the substrate being processed. The photomask is patterned to contain the desired configuration of features for the substrate. The patterned photomask causes the light energy to strike the resist material in accordance with the pattern.

[0007] Photolithographic reticles are fabricated from an optically transparent material, such as quartz (i.e., silicon dioxide, SiO_2). The reticle includes a pattern of opaque material that inhibits the light from exposing portions of the substrate in accordance with the desired pattern. A thin opaque layer of metal, typically chromium, is disposed on the surface of the reticle. This light-shielding layer is patterned to correspond to the features to be transferred to the substrate, such as transistors or polygates. The metallic material is patterned using conventional laser or electron beam patterning equipment to define the critical dimensions to be transferred to the metal layer. The metal layer is then etched to remove the metal material not protected by the patterned resist, thereby exposing the underlying quartz material and forming a patterned photomask layer. Photomask layers thus allow light to pass therethrough in a precise pattern onto the substrate surface.

[0008] In photolithography, the exposed material may either be a positive resist or a negative resist. In a positive resist, the exposed resist material on the substrate

is removed, while in a negative resist, the unexposed portions are removed. Removal is typically by a chemical process to expose an underlying substrate material. The exposed underlying substrate material may then be etched to form patterned features in the substrate surface while the retained resist material remains as a protective coating for the unexposed underlying substrate material. In this manner, contacts, vias, or interconnects may be formed by exposing the resist to a pattern of light through a photolithographic reticle having a photomask layer disposed thereon.

[0009] In an iterative convergence, the method for fabricating a patterned reticle itself involves a deposition and subsequent etching process. In this respect, a metal layer is first deposited on a top surface of a glass reticle. Thereafter, selected portions of the metal layer are removed through etching. Various types of etching processes are used for etching the metal layer from a reticle. One such etching method is known as plasma etching. In order to perform plasma etching, a glass reticle is first placed within a process chamber. More specifically, the glass reticle is placed on a pedestal. In a plasma etching process, the pedestal serves as a cathode. To this end, the metallic pedestal is given RF power. Power applied to the pedestal creates a substrate bias in the form of a negative voltage on the upper surface of the reticle. This negative voltage is used to attract ions from a plasma formed above the reticle in the chamber. The plasma is formed by the application of power to one or more inductive coils at the top of the chamber. The inductive coils generate and sustain the plasma above the pedestal and reticle. Thus, a voltage drop is induced across the pedestal that draws ions to the upper surface of the reticle, thereby etching a metallic layer.

[0010] Because the reticle is formed from a material having a low dielectric constant, e.g., glass or quartz, the amount of RF power that is coupled through the reticle is low. This inhibits the gas plasma in reacting with the reticle surface. This limitation is compounded by a gap typically existing between the reticle and the supporting pedestal therebelow. In addition, when the surface area of the pedestal is large compared to the reticle area, the RF power may preferentially couple to other regions of the pedestal, producing a loss of RF power. Further, it has been observed that the use of a pedestal cover, e.g., cover ring and capture ring,

fabricated from a dielectric material is inadequate to lessen the power coupled through the region of the pedestal that is not immediately below the reticle.

[0011] Therefore, there is a need for a plasma etching apparatus that aids in the chemical reaction between a gas plasma and a reticle. In addition, there is a need for a pedestal fabricated from a material that does not contribute to the power loss across the reticle during a plasma etching procedure.

SUMMARY OF THE INVENTION

[0012] The present invention generally provides an improved pedestal for supporting a substrate and related substrate support hardware. The pedestal has greatest application during a plasma etching process, such as for a quartz photomask, or "reticle."

[0013] The pedestal defines a body, and a base along on an upper surface of the body. The body receives an RF power during substrate processing. The substrate support base has an outer edge, and an intermediate substrate support ridge for receiving and supporting the substrate. At least a portion of the substrate support base outside of the intermediate substrate support ridge is fabricated from a dielectric material, or material having a lower dielectric constant than the remaining support base. An example is quartz. Quartz has a lower dielectric constant than the materials typically used for fabricating the pedestal body or cover, e.g., alumina. The placement of quartz allows greater RF power to be coupled through the reticle, thereby enhancing the plasma etching process. It also provides greater control over the relative amount of RF power coupled through the reticle.

[0014] In one aspect, a layer of dielectric material is placed along the top of the support base of the pedestal body. In another embodiment, the entire cross-sectional thickness of the support base that encompasses the supporting ridge is fabricated from a dielectric material. In one embodiment, a separate substrate support assembly is disposed on the base to facilitate the transfer of the substrate onto and off of the pedestal, with the substrate support assembly being fabricated from a dielectric material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are, therefore, not to be considered limiting of its scope.

[0016] Figure 1 is a cross-sectional view of a plasma etching chamber as might contain the pedestal of the present invention. The chamber shown in Figure 1 is exemplary.

[0017] Figure 2 presents an exploded perspective view of the substrate support member of Figure 1.

[0018] Figure 3 shows a perspective cutaway view of one embodiment of a pedestal of the present invention.

[0019] Figure 4 provides a cross-sectional schematic view of a pedestal of the present invention. A portion fabricated from a dielectric material is shown.

[0020] Figure 5 presents a cross-sectional schematic view of a pedestal of the present invention, in an alternate embodiment. A portion fabricated from a dielectric material is again shown.

DETAILED DESCRIPTION OF THE INVENTION

[0021] Aspects of the invention will be described below in reference to an inductively coupled plasma etch chamber. Suitable inductively coupled plasma etch chambers include the Decoupled Plasma Source (DPS™) chamber available from Applied Materials, Inc., of Santa Clara, California, or the ETEC Tetra™ photomask etch chamber available from ETEC of Hayward, California. A two-coil chamber, such as the Tetra II™ decoupled plasma source chamber available from Applied Materials, Inc.may also be employed. Other process chambers may be used including, for example, capacitively coupled parallel plate chambers and

magnetically enhanced ion etch chambers, as well as inductively coupled plasma etch chambers of different designs. Although the processes are advantageously performed with the DPS™ processing chamber, the description in conjunction with the DPS™ processing chamber is illustrative and should not be construed or interpreted to limit the scope of aspects of the invention.

[0022] In order to perform plasma etching, a substrate, e.g., a glass reticle, is placed within a processing chamber. An example of such a chamber is schematically shown in **Figure 1**. The process chamber **100** of **Figure 1** has a substrate support member **200** disposed therein, and a substrate handler blade **300** positioned adjacent thereto. Substrates **222** are shown positioned on both the substrate support member **200** and the handler blade **300**.

[0023] The processing chamber **100** is configured to receive a substrate **222**, such as a glass reticle to be processed through plasma etching. The substrate **222** enters and exits the chamber **100** through a gate **161**. The gate **161** serves as a port, and also isolates the chamber **100** environment during reticle processing. The substrate **222** is transported via a substrate cassette, using the substrate handling blade **300**. The substrate handling blade **300** transfers the substrate **222** between a separate transfer chamber (not shown) and various processing chambers. In this respect, it is understood that the reticle fabrication process involves multiple steps, and that different steps are typically conducted in different chambers that mechanically cooperate with the substrate handling blade **300**. An example of such a processing system is a Centura™ processing system available from Applied Materials, Inc. of Santa Clara, California.

[0024] The process chamber **100** generally includes a cylindrical side wall **162**. The side wall **162** helps define the chamber body, and also supports the gate **161**. The chamber **100** is also defined by a chamber bottom **167**, and an energy transparent ceiling or lid **163**. An inductive coil **176** is disposed around at least a portion of the lid **163**. The chamber body **162** and chamber bottom **167** of the chamber **100** can be made from a metal, such as anodized aluminum. The lid **163** is fabricated from an energy transparent material such as a ceramic or other dielectric material.

[0025] As mentioned above, the chamber **100** holds a substrate support member **200**. The support member **200** supports the substrate **222** during processing. A plasma zone **164** is defined by the process chamber **100** above an upper surface of the substrate support member **200**. During processing, process gases are introduced into the plasma etch chamber **100** through a gas distributor **172**. The gas distributor **172** is peripherally disposed about the substrate support member **200**. The gas distributor **172** is shown illustratively, and may be disposed in other configurations, such as disposed at the top of lid **163**. Process gases and etchant byproducts may be exhausted from the process chamber **100** through an exhaust system (not shown). An optional cooling line **184** is provided in the pedestal **200**. for controlling the pressure in the plasma etch chamber **100**. An endpoint measurement device may optionally be included to determine the endpoint of a process performed in the chamber **100**.

[0026] With respect to the substrate support member **200** itself, the support member **200** defines a pedestal for the substrate **222** during processing. The support member **200** first comprises a body **206**. The body **206** has an upper surface that defines a substrate support base **210** (seen in **Figure 2**). In one arrangement, the substrate support base **210** is a separate piece mounted on an upper surface of the body **206**. An optional substrate supporting assembly **215** is preferably provided over the base **210** to aid in transporting the substrate **222** into and out of the chamber **100**. The substrate supporting assembly **215** is shown in detail in **Figure 2**. Only the capture ring **216** of the supporting assembly **215** is seen in **Figure 1**.

[0027] Referring back to **Figure 1**, the body **206** of the substrate support member **200** is mounted on a bulk head assembly, or shaft, **102**. In the embodiment shown, the body **206** is stationary in the chamber **100**; however, in an alternative embodiment, the body **206** (or a portion of the body **206**) may be moveable within the chamber **100**. In one arrangement, the body **206** of the substrate support member **200** is mounted on a stainless steel base **104**. The base **104** is typically disposed on the bottom of the processing chamber (not shown in **Figure 2**), with the bulk head assembly **102** mounted through the bottom of the processing chamber **100** and coupled to the body **206**. The substrate support member **200** is adapted to

maintain vacuum isolation between the interior of the chamber **100** and the outside environment. Power, electrical controls, and backpressure gases may be provided to the substrate support member **200** via the shaft **102**.

[0028] **Figure 2** presents an exploded perspective view of one embodiment of a substrate support member **200**. From **Figure 2**, the body **206** and support base **210** are more clearly seen. It can also be seen that a cathode **112** is disposed in the support base **210**. The cathode **112** may optionally vertically extend above the surface of the body **206**. The cathode **112** is electrically coupled to an electrode power supply **178** to generate a capacitive electric field in the plasma etch chamber **100**. Typically an RF voltage is applied to the cathode **112** while the chamber body **162** is electrically grounded. Power applied to the pedestal **200** creates a substrate bias in the form of a negative voltage on the upper surface of the substrate **222**. This negative voltage is used to attract ions from the plasma formed in the chamber **100** to the upper surface of the substrate **222**. The capacitive electric field forms a bias which accelerates inductively formed plasma species toward the substrate **222** to provide a more vertically oriented anisotropic etching of the substrate **222**.

[0029] Channels **211** (three are shown) are also disposed through the body **206**, and house internally movable lift pins **214** therein. As will be discussed further below, the lift pins **214** engage the lower surface of a capture ring **220** to move the capture ring **220** vertically within the chamber **100** relative to the cover ring **216**. The body **206** may comprise a temperature controlled base adapted to regulate the temperature of the substrate support assembly **215**, and thus, a substrate **222** disposed thereon. The body **206** can be made of a material inert to the process formed in the processing chamber including, for example, aluminum oxide, or aluminum, and substrate support assembly **215** components can be made of aluminum or aluminum oxide. The body **206** may include fluid channels, heating elements, e.g., resistive heating elements or other temperature control members.

[0030] In the support member arrangement of **Figure 2**, the substrate support member **200** includes a separate substrate supporting assembly **215**. The substrate supporting assembly **215** generally includes a cover ring **216** and a capture ring **220**.

[0031] Referring first to the cover ring **216**, the cover ring **216** is preferably a circular ring having an upper surface **219** and support shoulders **218**. The substrate supports **218** define shoulders for receiving a substrate (not shown). In one arrangement, the substrate supports **218** define opposing raised surfaces **221**, **223** that each includes an inner sloped surface for receiving a substrate. A central opening **225** is formed in the upper surface **219** of the cover ring **216**. The two raised surfaces **221**, **223** are generally disposed on opposing sides of the central opening **225**. The first raised surface **221** defines an essentially linear raised surface extending along the length of one side of the central opening **225**. The second raised surface **223** defines an arcuate raised surface **221** having an outer diameter **224** and an inner diameter **226**. The outer diameter **224** generally matches the radius of the cover ring **216**, while the inner diameter **226** conforms to the geometry of the central bore **225** along one or more sides of the bore **225**. The upper surface **219** and the raised surfaces **221**, **223** may be monolithic or may be made of separate components connected together.

[0032] The capture ring **220** defines an arcuate base plate having an inner diameter **207** and an outer diameter **202**. A central bore **206** is formed within the inner diameter **207** of the capture ring **220**. The diameters **207**, **202** of the capture ring **220** are not continuous, but retain an opening that serves as part of the bore **206**. As with the cover ring **216**, the capture ring **220** includes substrate supports **204**, **205**. The substrate supports **204**, **205** generally follow the inner diameter **207** of the capture ring **220**. In the arrangement of Figure 2, the supports **204**, **205** define shoulders disposed along the inner perimeter **207**. The substrate supports **204**, **205** and the base plate **202** form a substrate receiving area. The shoulders **204**, **205** and the base plate **202** are adapted to mate with the substrate supports **218** on the cover ring **216**. When the capture ring **220** is rested upon the cover ring **216**, the substrate supports **205** for the capture ring **220** are co-planar with the substrate supports **218** for the cover ring. The capture ring **220** is dimensioned to rest on the cover ring **216** without covering the two raised surfaces **221**, **222** on the cover ring **216**. Together, the substrate supports **205**, **218** may then seamlessly receive a substrate (not shown).

[0033] The capture ring **220** moves vertically above the cover ring **216**. In operation, the lift pins **214** move the capture ring **220** vertically above the cover ring **216** during substrate transfer, and then lower the capture ring **220** onto the cover ring **216** for substrate processing. The use of lift pins in the semiconductor fabrication business is known, and those of ordinary skill in the art will understand from this disclosure how the lift pins may be fabricated.

[0034] Channels **217** are formed through the cover ring **216** to enable the lift pins **214** disposed through the body **206** to move therethrough and lift the capture ring **220** vertically. The vertical movement imparted by the lift pins **214** is used to lift the capture ring **220** to effectuate substrate transfer between the substrate handler blade **300** and the capture ring **220**. The lift pins **214** move the capture ring **220** vertically above the cover ring **216** during substrate transfer, and then lower the capture ring **220** onto the cover ring **216** for substrate processing.

[0035] To begin processing, the reticle **222** (or other substrate) is positioned on the surface of the pedestal **200**. Etch gases are then introduced into the chamber **100**. To this end, a process gas source supplies gas, such as an oxygen based gas, through a gas input line **172**. In the arrangement of **Figure 1**, the input line **172** feeds gas into the side of the lid **163**. However, gas may also be introduced through nozzles (not shown) in the top of the lid **163**. Chamber pressure is controlled by a closed-loop pressure control system (not shown).

[0036] As gas is injected into the chamber **100**, a gas plasma is created. Plasma is formed by the application of power to one or more inductive coils **176** at the top of the lid **163**. In the chamber **100** of **Figure 1**, two RF coils **176** are used, with one being an outer coil and one being an inner coil. A power supply **177** and matching network is used to apply power to the inductive coils **176**. The inductive coils **176** generate and sustain the plasma above the pedestal **200** and substrate **222**. In one arrangement, approximately 125 Watts is applied to the coils **176** at a frequency of about 13.56 MHz, to produce and maintain an oxygen-comprising plasma over the surface of the reticle **222**. In one arrangement for a dual coil system, approximately 400 Watts is applied to the coils **176** at a frequency of about 13.56 MHz, to produce and maintain a chlo7rine-and-oxygen-comprising plasma over the surface of the

reticle **222**. For a single coil system, the coils may provide a DC bias of about 340 to 410 Volts on the reticle surface.

[0037] **Figure 3** shows a perspective cutaway view of one embodiment of a pedestal **300** of the present invention. The pedestal **300** is configured to receive and support a substrate in a plasma etching chamber. Preferably, the substrate is a photolithographic reticle, and the chamber is a plasma etching chamber, such as the chamber shown in **Figure 1**, and discussed above.

[0038] The pedestal first comprises a body **306**. In the arrangement of **Figure 3**, the body **306** is a generally cylindrical object, though other shapes may be employed. The body **306** includes an upper surface **310** that serves as a substrate support base. In the arrangement shown in **Figure 3**, the support base **310** has a radial outer diameter **324**. The base **310** also has an intermediate shoulder **326** that forms a four-sided support ridge **325**. The support ridge **325** serves to support the reticle above the pedestal **300** during processing. The support ridge **325** is preferably fabricated from a metallic material. The term "support ridge" means any raised surface feature of any height or shape along the support base **310** that contacts and supports a substrate **222** during processing.

[0039] The support base **310** is typically configured to receive a cover (not shown) to further support a reticle during processing. The cover may be configured to operate as the substrate support assembly **215** described above.

[0040] In the novel pedestal **300** of the present invention, at least a portion of the body **306** is fabricated from a dielectric material. In the cutaway view of **Figure 3**, the dielectric material portion of the body **306** is shown at **318**. Dielectric material **318** is selectively used in the upper surface **310** so as to define a dielectric ring generally about the perimeter of the body **306**. The dielectric material **318** is placed outside of the contact point, e.g., support ridge **326**, for the reticle **222** on the pedestal **300**. The dielectric material portion **318** of the body **306** may comprise two or more separate components (not shown) joined together to form the dielectric portion **318** of the body **306**. The two or more dielectric members may be fabricated from materials having different dielectric properties. The benefit of using material of

different dielectric properties is to control the relative amount of RF power coupled through the reticle, as the thickness and dielectric property of the reticle substrate, e.g., quartz, is fixed.

[0041] The dielectric material portion **318** of the body **306** may be of different thicknesses. This is demonstrated in the schematic embodiments shown in **Figures 4** and **5**. **Figure 4** provides a cross-sectional view of a pedestal **300'** of the present invention. The pedestal **300'** is shown schematically. Likewise, **Figure 5** presents a cross-sectional view of a pedestal **300'** of the present invention, in an alternate embodiment. The pedestal **300''** is again shown schematically. In each view, a reticle **222** is shown being supported on the respective pedestal **300', 300''**. Further, in each view a cover **315** is provided. The cover **315** may be configured in accordance with the cover **215** shown in the exploded view of **Figure 2**. The cover **315** is preferably fabricated from a dielectric material. The use of different dielectric material thickness is to adjust or control the relative RF power coupled to the reticle. One benefit of using a dielectric material is it enables the use of two control knobs, that is knobs for dielectric constant and thickness. This, in turn, enables the operator to change the relative amounts of RF that goes into the reticle versus the RF power that goes to the pedestal area surrounding the reticle. The dielectric thickness and type may be such that the relative amount is the same for uniform power distribution, or different if needed for compensating for the etch process.

[0042] Dielectric material is shown at **318** in both **Figure 4** and in **Figure 5**. In **Figure 4**, the dielectric material **318** resides along the top of the upper support base **306**. In **Figure 5**, the dielectric material **318** defines substantially the entire thickness of the upper support base **306**. In either instance, the dielectric material **318** is preferably placed outside of the contact point for the reticle **222** on the pedestal **300**.

[0043] As can be seen, the pedestals **300, 300', 300''** place dielectric material along a periphery of the upper substrate support body **306**. The dielectric material **318** may be polymeric or ceramic. An example of a polymeric material is Ardel™ polyarylate material manufactured by Amoco polymers. Another example is Vespel™ polyimide from DuPont. Still another example is a plastic material sold

under the trade name Ultem™. Yet another example is a synthetic rubber material. An example of a suitable ceramic material is aluminum oxide. Another example of an acceptable dielectric material is quartz. The selected use of dielectric material **318** has the effect of changing the amount of RF power coupling into the reticle during a plasma etching procedure. In this respect, during a plasma etching procedure, the body **306** receives power, such as an RF power. By using dielectric material on the periphery of the body, the potential drop across the pedestal is changed to have a value less than the region where the reticle rests, i.e., inside of the substrate support ridge **326**. The portion of the pedestal **300** within the substrate support ridge **326** remains metallic in order to efficiently conduct waste heat away from the reticle **222**.

[0044] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.